[Proc. Roy. Soc. Victoria, 27 (N.S.), Part I., 1914.]

Art XI.—*The Petrology and Mining Geology of the Country near Queenstown.*

By NORMAN R. JUNNER, B.Sc.

(Wyselaskie Scholar in Geology, University of Melbourne, 1913; 1851 Scholar in Geology, Imperial College of Science, London S.W., 1914).

(With Plate XIX).

[Read 9th July, 1914.]

Contents.

1. Introduction and Previous Literature.
2. General Geology:—
   (a) Silurian sediments.
   (b) Quartz diorite, Yow Yow.
   (c) Alteration of the diorite.
   (d) Quartz porphyry, One Tree Hill.
3. The Caledonia Gold Field:—
   (a) History and production.
   (b) One Tree Hill.
   (c) Panton Hills (Oram's Reef).
   (d) Yow Yow.
   (e) Alluvial.
   (f) Future possibilities, secondary enrichment, etc.
4. Summary and Conclusions.

1.—Introduction and Previous Literature.

The following contribution is descriptive of certain features in the geology of portion of the Parish of Queenstown. Unfortunately, the field-work was not completed, owing to the transference of the writer to England, and as a result no geological map of the area has been prepared by him. The chief purpose of the paper is to present the results of a study of the chemical and petrological features and metasomatic alteration of an hitherto undescribed intrusion of quartz diorite near Queenstown. Further, attention is drawn to the former richness and future possibilities of an almost forgotten goldfield. Previous references to the geology of this area are scant, and are of no great importance. The following papers dealing with the area are chiefly concerned with the mining geology, and general mining features, and very little space in them is devoted to purely geological questions.

(1) 1855-56. A. R. C. Selwyn.—"Report on the Geological Structure of the Colony of Victoria, the Basin of the Yarra, etc." Votes and Proc. Leg. Council, Victoria, vol. ii., pt. 1.

(2) 1889. J. Stirling.—"Report on the Mining and Prospecting Operations in the Gippsland and Castlemaine Districts." Appendix H, Quart. Reports of the Mining Surveyors and Registrars of Victoria.

(3) 1894. R. A. F. Murray.—"Report on the Auriferous Country in the Neighbourhood of Queenstown." Prog. Rep. Vict. Geol. Surv., No. viii., pp. 67, 68.

(4) 1894. D. B. Walker.—"Report on Neglected Goldfields." Spec. Rep. Dep. Mines, Victoria.

(5) 1895. J. Stirling & O. A. L. Whitelaw.—"Reports on Rapid Surveys of the Goldfields, Parishes of Warrandyte, Nillumbik, Greensborough, and Queenstown (with Map)." Spec. Rep. Mines Dept., Victoria.

(6) 1899. H. S. Whitelaw.—"Antimony Ores in Victoria." Prog. Rep. Vict. Geol. Surv., No. X.

2.—General Geology.

A.—Silurian Sediments.

These are the northern extension of the same folded series of sandstones, shales, and gritty beds that occur near Warrandyte and Diamond Creek, and with the exception of the igneous rocks near Yow Yow and One Tree Hill, they cover the whole of the area described in this paper. The strike of these beds is consistently east of north, varying from north 10° east to north 50° east. As in the sediments of the country to the south near Warrandyte and Diamond Creek, fossils are relatively scarce, and the only ones found by the present writer were two specimens of Chonetes allied to Chonetes melbournensis, which latter form is restricted to the Melbournian division of the Silurian. These fossils were discovered in black, sandy, occasionally gritty shales from the mullock-tip of a shaft on the Victoria line of reef, One Tree Hill. Selwyn has recorded fossils similar to those occurring in the gritty beds near Warrandyte, from Watson's Creek about six miles north of Warrandyte. None of these forms have been described, and therefore they afford no clue to the precise age of these beds. In the absence, therefore, of more detailed palaeontological work in this area, nothing definite can be said at present respecting the age of these sediments.

On stratigraphical grounds, in the assumed absence of major faulting and inversion, the relative stratigraphical position of the beds near Queenstown can be fairly well gauged from sections afforded by two traverses, one along the creek road from Hurst's Bridge to Queenstown, and the other along the road from Kangaroo Grounds through Christmas Hills to Yarra Glen. Considering in detail the first section, the beds near Hurst's Bridge show considerable lithological similarity to those at Diamond Creek, and, further, the Templestowe anticline, which is so marked a feature of Diamond Creek, is seen in a railway cutting immediately south of the Hurst's Bridge railway station. Traversing eastwards from Hurst's Bridge, the strata dip consistently east, at an average angle of about 45°, until about a mile and a quarter beyond Cottle's Bridge,[1] where the Bulleen syncline crosses the road section. This fold, at this point, is not the important feature that it is to the south near Research and the Yarra River.[2] The strata near the axis of the fold are much steeper than they are further south, and soon give place to east-dipping beds with an anticline between. This anticline is the northerly continuation of a fold, not named, but shown on a map accompanying the author's report on the Diamand Creek area.[3] Continuing east, the beds appear to dip east until close to Queenstown township, where a westerly dip is present. It is evident, from this section, that the strata near Queenstown are stratigraphically much superior to the beds of the Templestowe anticline near Hurst's Bridge.

The Warrandyte anticline, devoid of its minor folds, crosses Watson's Creek at a point near to where the creek changes from a N.E.-S.W. course to one nearly east and west. The fold continues in a north-easterly direction to One Tree Hill, where the structure is anticlinal, and the beds are lithologically similar to those of Warrandyte. Sections along the road from Kangaroo Ground to Yarra Glen show that the predominant dip is an easterly

1 Vide, Parish plans of Greensborough and Queenstown for this and other local names occurring in this paper.

2 Vide, J. T. Jutson, "The Structure and General Geology of the Warrandyte Goldfield and adjacent Country." Proc. Roy. Soc. Victoria, vol. xxiii. (n.s.), pt. ii., p. 523, 1910.

3 Proc. Roy. Soc. Victoria, vol. xxv. (n.s.), pt. ii., 1912

one, after crossing the Warrandyte anticline, and that the strata of this fold are stratigraphically much inferior to the Yeringian beds near Yarra Glen. A general interpretation of the structure, therefore, indicates that the beds near Queenstown are superior to those of the Templestowe anticline, which have been shown by the author in a previous paper to be probably Melbournian or older in age,[1] and to be inferior to the Yeringian strata occuring to the east of this area. Recapitulating, the age of these beds near Queenstown may be regarded tentatively, in the absence of further palaeontological evidence, as either Melbournian or Yeringian; possibly both series are present in the area described.

B.—Quartz Diorite, Yow Yow.

On the spur separating Salter's Gully from Yow Yow Gully, and about one and a-half miles east from Queenstown, a rather tough bluish-coloured, holocrystalline rock, composed chiefly of hornblende and felspar, is seen to outcrop. About the surface, scattered, exfoliated boulders are present in places, but more frequently, and especially near the northern and southern limits of this rock, it is decomposed to a brownish coloured granular mass. The depth of surface decomposition varies, extending in places to over 150 feet.

The intrusion is roughly elliptical in plan and the walls, where examination was possible, appeared to conform approximately in strike and dip with the surrounding strata. On the surface, the sediments in juxtaposition with the intrusion exhibit very little alteraton, and, in fact, the sediments near Queenstown township and Yow Yow Gully away from the intrusion, are much more indurated. According to the District Mining Surveyor,[2] a tunnel driven in 1860 from Salter's Gully, passed through a band of hard altered sandstone, resembling basalt, before reaching the diorite. This points undoubtedly to hornfels, but apparently the occurrence of this rock in proximity to the diorite, is exceptional. In its approximate conformity with the strata, absence of marked contact alteration, petrological and chemical characteristics, and associated auriferous quartz veins, the intrusion is very closely allied to the so-called "dyke bulges" of the Wood's Point district.

Chemical Relations.—A chemical analysis of a typical specimen of the diorite from the Caledonia Mine, Yow Yow, was made by

1 Op. cit. p. 317.

2 Vide, Mining Surveyors' Reports, 1860.

the writer at the Imperial College of Science, London. For purposes of comparison, two very similar analyses of other Victorian diorites are appended.

	I.	II.	III.
SiO_2	52.53	49.65	52.03
Al_2O_3	18.78	16.73	23.57
Fe_2O_3	1.52	0.31	1.60
FeO	6.60	8.99	6.90
MgO	3.02	5.88	5.39
CaO	7.21	7.87	7.80
K_2O	1.73	0.80	1.34
Na_2O	2.54	3.10	2.37
H_2O+	2.24	2.50	1.27
H_2O-	0.53	0.14	0.26
CO_2	0.39	1.08	
P_2O_5	0.32	0.04	
MnO	0.14	0.14	
TiO_2	2.16	2.81	n.dt
S	n.det	n.det.	
(NiCo)O	str. tr.	NiO tr.	
	99.71.	100.04.	99.60.
Sp. Gr.	2.81	2.91	2.855

American Classification.

Magmatic Name	Bandose near Hessose	Hessose	Hessose

I. Quartz Diorite, Caledonia Mine, Queenstown. Analyst, N. R. Junner.

II. Quartz Diorite, Morning Star Dyke, Wood's Point. Analyst, N. R. Junner.

III. Quartz Diorite, Dargo. A. W. Howitt.[1]

The chemical analysis of the Queenstown rock confirms its microscopical determination as a quartz diorite. The marked excess of soda over potash, and the relatively high percentage of lime, finds expression in the predominance of soda lime felspars over potash felspars. The high percentages of water and carbon dioxide are due to the presence of chlorite and calcite, and do not signify that the rock has suffered weathering, as these minerals are regarded as being formed immediately after the consolidation of the rock.

1 Vide, Proc. Roy. Soc. Victoria, 1887.

Further, in weathered rocks, ferric oxide always predominates over ferrous oxide, whilst in the Queenstown rock the reverse is the case.

Petrology.—All specimens examined (some of them from the Caledonia mine coming from greater depths than 200 feet) showed considerable alteration, resulting in the formation of such secondary minerals as chlorite, epidote, sericite, carbonates, leucoxene, pyrrhotite, and iron pyrites. In hand-specimen, the rock is even-grained, and consists of about equal quantities of salic and femic minerals, chiefly hornblende and felspar. Quartz is not visible macroscopically. Microscopically it is a holocrystalline, medium and even-grained rock, consisting essentially of brown hornblende, felspar (both orthoclase and plagioclase), quartz, ilmenite apatite, and the above-mentioned secondary minerals.

The hornblende is the brown variety, which is so characteristic of the igneous rocks of the Walhalla, Wood's Point gold belt. In most sections, little of it remains, as it has been extensively changed to chlorite and epidote. It is usually hypidiomorphic and often includes ilmenite and felspar, showing that it consolidated later than these minerals. Tremolitic outgrowths in optical continuity with the brown hornblende are occasionally present. Twinning, with twin and composition plane parallel to the orthopinacoid, is not uncommon. It is markedly pleochroic, exhibiting the following colour scheme:—

X light yellow brown.
Y fairly dark brown.
Z very dark brown.
and $Z > Y > X$ as usual.

Plagioclase occurs as beautifully zoned crystals, showing the usual albite twinning, and occasionally twinned according to the Carlsbad and Pericline laws. Certain sections of zoned plagioclase show no signs of the albite lamellae, but exhibit basal cleavage, and are therefore cut approximately parallel to 010. One such section gave an extinction angle of -16° from the 001 cleavage for the central core, and $+21^{\circ}$ from the same cleavage for the clear outer zone, indicating a kernel of labradorite (Ab An), and an outer zone of albite. Almost invariably the refractive index of the clear exterior zone of the felspar is less than that of quartz, proving it to be albite. Symmetrical extinction angles, from the albite lamellae, range as high as 43° for the cores, showing plagioclase near Bytownite. A few phenocrysts of untwinned or simply twinned kaolinised felspar, having a refractive index less than that of quartz, are orthoclase. Calculating the percentage of felspars from the chemical analysis, according to the American method, we get the following result :—

Orthoclase, 10.01%.
Albite, 21.48%.
Anorthite, 31.69%.

Quartz is interstitial, and occurs in irregular shaped, pellucid grains characterised by fairly abundant fluid inclusions containing bubbles. Ilmenite is farly common, and is present in skeletal and malformed crystals, occasionally showing hexagonal outlines. It is associated frequently with its replacement product, leucoxene, and the triangular parting is often rendered very evident by relict ilmenite bars surrounded by leucoxene. Extraction of any magnetic particles from the powdered rock by a weak bar magnet, showed that only an inappreciable amount of magnetite was present.

The accessory minerals include apatite, and zircon ; the latter in chloritic areas is often surrounded by pleochroic haloes.

Of the secondary minerals, chlorite is the most abundant, and is usually intimately associated with hornblende and epidote. It is undoubtedly secondary after hornblende in nearly all cases, and occasionally idiomorphic outlines of the latter mineral are preserved in the chlorite pseudomorphs. The chlorite is of the variety pennine, giving ultra blue polarisation colours. It is decidedly pleochroic X—Y, apple green, Z, yellow, and is microspherulitic in part. Slightly yellow coloured grains of epidote, referable to pistacite, almost invariably accompany the chlorite derived from the hornblende. Some of the epidote is present as radial aggregates. Fibres of a colourless mineral, having a refractive index between that of chlorite and epidote, and exhibiting very high polarisation colours, are probably calcite. It appears the most of the magnesia, and part of the iron of the original hornblende, have gone to form chlorite, and the lime and the other portion of the iron, with some alumina and water, have yielded epidote. Carbonate occurs generally in massive cleaved, and twinned plates, filling interstices between the quartz and the felspar. It does not occur replacing these minerals or the hornblende to any marked extent. Noteworthy is the fact that it differs very markedly from the metasomatic granular and dusty carbonate so commonly developed in these rocks, as a result of hydrothermal vein alteration. A little sericite replaces plagioclase, especially along cleavage planes. In all sections examined a little sulphide is present, showing marked preference for areas of ilmenite and undoubtedly replacing the latter mineral in many cases. The sulphide is easily recognised as pyrrhotite by its lighter colour than ordinary pyrites in reflected light, and by its irregular outlines. It is proved without doubt by extracting the magnetic minerals from the powdered rock, and either examining the separated material under a microscope, or by adding a little hydrochloric acid to the separated grains, when sulphuretted hydrogen is readily detected. A very little iron pyrites also accompanied the pyrrhotite thus separated. Pyrrhotite though present in practically all sections, is most common in pegmatitic veins intersecting the diorite.

Acid Dykes in Diorite.—Numerous small aplitic and pegmatitic dykes intersect the diorite. The pegmatites, in general, consist chiefly of large hornblende prisms and colourless felspar, whilst in the aplite dykes, hornblende is rare or absent, and microscopic sections show that orthoclase predominates over plagioclase. Specimen No. 120, Caledonia Mine, is typical of these aplites. The hand specimen of the rock is of a light yellowish colour. Abundant stibnite and pyrites are visible, disseminated throughout the specimen. Microscopically, it is a fairly even-grained, holocrystalline rock, with granitoid texture, and composed of the following minerals:—Quartz, felspar, muscovite, iron and arsenical pyrites, stibnite, carbonate and sericite. No femic minerals are present, and quartz is in slight excess of the total felspar. Orthoclase, generally untwinned and greatly kaolinised, preponderates over plagioclase, which is also much weathered. Sections of plagioclase occasionally show intersecting lamellar twinning according to the albite and pericline laws. Zoning is rare, and in nearly all sections, the mean refractive index of the plagioclase, determined by the Becke method, is less than that of quartz, indicating oligoclase or albite. Maximum extinction angles of 20° from the albite twin planes, prove albite. A few rectangular sections of muscovite with the usual separated leucoxene or rutile, represent, without doubt, hornblende or biotite in the original rock. Most of the mica, however, is of the sericitic type and occurs in the usual aggregates of foils, sometimes arranged radially and often replacing felspar. Veinlets of carbonate and quartz carrying stibnite, traverse the rock. Acicular crystals of stibnite, together with a little ordinary and arsenical pyrites, also occur promiscuously distributed throughout the section. Certain miscroscopic veins of quartz, which intersect plagioclase crystals, are seen to grade insensibly into the primary quartz grains of the rock, and are therefore also primary.

Comparison of Queenstown Diorite with the Morning Star Diorite, Wood's Point.—The chemical analyses of these rocks show close similarities. From the relative percentage of the alkalies, we should expect a greater proportion of orthoclase in the Queenstown diorite than in the Morning Star rock, and microscopical investigation confirms this belief. The high percentage of water in both analyses is expressed by the relative abundance of chlorite after hornblende. The higher percentages of ferrous oxide and titanium dioxide in the Morning Star rock indicate relatively more hornblende and ilmenite, than in the Queenstown rock.

Mineralogically the rocks closely resemble one another. Especially characteristic is the occurrence of brown hornblende in each of them. Zoned felspars are not usually present in the Morning Star diorite, and epidote is uncommon. Micropegmatite, which is characteristic of the Wood's Point rock, is only present in pegmatitic veins at Queenstown.

C.—Alteration of the Diorite.

Three types of alteration are recognisable.

I. A regional propylitic alteration during, or immediately after, the consolidation of the rock, at relatively high temperature and pressure, resulting in the formation of chlorite, epidote, leucoxene, carbonate, pyrrhotite, and a little sericite.

II. Hydrothermal alteration near the vein walls at much lower temperature and pressure, resulting in extensive sericitisation and carbonation, and in the disappearance of the femic minerals, hornblende, chlorite, and pyrrhotite; and their replacement by muscovite, carbonates, and pyrites.

III. Surface decomposition by present-day vadose solutions. Kaolinisation is referable to the action of these solutions.

I. On most mining fields where ore deposits occur in igneous rocks, a regional propylitic alteration of the country rock can be recognised in addition to the hydrothermal alteration near the veins, but differences of opinion exist as to the cause of this alteration. Propylitisation[1] of the andesites at Tonopah, Nevada, has been ascribed by Spurr[2] to the vein-forming waters filtering through

1 Propylitisation is here used in the sense defined by Vogt, "Genesis of Ore deposits," 1901, and Lindgren, "Mineral Deposits," p. 446, 1913, and not in the restricted sense of other writers.

2 Geology of the Tonopah Mining District, Nevada, U.S.G.S., P.P., No. 42, 1905.

the rocks. According to Spurr, there are transitions between the propylitic and sericitic facies. According to Kirk,[1] the chloritic and sericitic phases of the alteration of the Butte Granite merge into each other very gradually. Stelzner and Bergeat[2] and Schumacher[3] consider the propylitisation of the Tertiary andesites of Transylvania to be independent of the vein solutions and much earlier, and Finlayson[4] comes to similar conclusions with respect to the alteration of the andesites of the Hauraki goldfield.

The author's study of the auriferous diorites of the Wood's Point gold belt, and also of the related rock from Queenstown, has convinced him that the regional propylitic alteration undergone by these rocks is independent of the vein solutions and that the effects of the latter are superimposed upon the propylitisation. The propylitic alteration is regional, and no relation appears to exist between the amounts of chlorite, epidote and pyrrhotite, and the proximity to a vein fissure. These minerals are just as abundant 20 feet away from the vein fissure as they are two feet away from it. Certainly no transition occurs between the two types of alteration such as Spurr has described at Tonapah.[5] Further, the minerals developed in the propylitic facies are generally characteristic of high temperature deposits. Both chlorite (Pennine) and epidote are common in the crystalline schists, and contact metamorphic ore deposits, which are formed under considerable pressure and at relatively high temperatures. The vein solutions were undoubtedly moderately strong alkaline charbonate and sulphide solutions, and both the above minerals appear to be unstable in the presence of such.

Significance of Pyrrhotite.—Pyrrhotite is usually regarded as a high temperature mineral. Its occurrence as a primary mineral in certain basic rcoks, and its association with such undoubted high temperature minerals as garnet and magnetite in contact metamorphic ore deposits, clearly support this view. At Queenstown, small quantities of pyrrhotite occur distributed through the propylitised diorite. It is closely associated with the ilmenite and leucoxene, and in places occurs disseminated through these minerals. In one section, narrow parallel bars of ilmenite traverse an irre-

---

1 "Conditions of Mineralisation in the Copper Veins at Butte, Montana." Economic Geology, vol. vii., 1912.

2 "Die Erzlagerstätten." 1905-1906.

3 Zeitschr, f. prakt. Geol., pp. 1-85, 1912.

4 "Problems in the Geology of the Hauraki Goldfields, New Zealand." Economic Geology, vol iv., No. 7, 1909,

5 Op. Cit. p. 210.

gular shaped grain of pyrrhotite, suggesting an intergrowth of the two minerals. However, around the edges of the pyrrhotite, some leucoxene is seen, strongly suggesting that the pyrrhotite is replacing the leucoxene, and that the bars are relics of a former ilmenite grain. The iron, set free from the ilmenite in the change to leucoxene, has apparently united with sulphur from hydrogen sulphide in the gases or solutions, causing propylitisation, and pyrrhotite has formed.

Of late, much attention has been devoted in the laboratory to the study of the iron sulphides, and we are particularly indebted to American chemists for valuable syntheses of them. Of particular interest are the results of Allen, Crenshaw, and Johnston at the Carnegie Institute, Washington.[1] They have artificially prepared pyrrhotite by the direct union of iron and sulphur at 700°, and have shown that pyrite dissociates into pyrrhotite and sulphur in an atmosphere of sulphuretted hydrogen, at temperatures above 565°. The action is represented by the following equation :—

$$FeS_2 \rightleftarrows FeS(S)_n + (1-n)s$$

Pyrite Pyrrhotite Sulphur.

Above 565° the forward action proceeds, and below 565° pyrrhotite, in an atmosphere of hydrogen sulphide, passes into pyrites. The formation of pyrrhotite, and not pyrites in the Queenstown diorite, apparently by the attack of hydrogen sulphide on the ilmenite, should therefore have taken place at high temperature; however, not necessarily as high as 565,° as the dissociation temperature is dependent on the pressure. Pyrrhotite has also been formed synthetically by these authors in an acid environment, at temperatures between 80° and 225,° but the syntheses are undoubtedly inapplicable in our case, since the solutions causing propylitisation must have been alkaline.

Recapitulating, it is seen that the minerals formed during the propylitisation of the diorite, are, in their geological occurrence, usually fairly high temperature minerals. Microscopic and field evidence show that the propylitisation and sericitisation are independent, and that the effects of the latter alteration are superimposed upon those of the former. The chemical analysis of the rock shows, further, that the gases or solutions causing the alteration must have contained water, carbon dioxide, and sulphides. The composition of the original rock does not appear to have been

---

1 "The Mineral Sulphides of Iron." Amer. Jour. Sci., 4th ser., vol. xxxii., 1911.

greatly changed as a result of the alteration. It appears very likely that the mineralisers had their origin in the cooling magma, and that their escape was made possible by the relief of pressure during the intrusion of the diorite. The gases thus expelled from the magma would permeate the solidifying rock, and cause such alteration as has been described.

II. Hydrothermal alteration adjoining vein fissures. Narrow veins of auriferous quartz, generally only an inch or two in width, but as much as twelve inches wide in places, traverse the diorite. On either side of these veins, the country rock has been bleached for varying distances, generally less than one foot, and rendered much finer grained. Considerable development of pyrite and arsenopyrite together with some stibnite, has taken place in close proximity to the quartz veins. These sulphides are most abundant along the vein wall, and decrease in amount outwards. That the bleaching is a result of the alteration of the diorite by the vein solutions, is certain.

Specimen No. 140, Caledonia Mine, Yow Yow, shows an intermediate stage in the alteration. Macroscopically, it is a fairly even grained rock, greenish in colour, and showing fairly abundant pyrites scattered through it. A section of the rock examined microscopically shows no hornblende or felspar. The hornblende remaining from the propylitic alteration has not been first changed to chlorite, and then to carbonates and muscovite, but apparently it has in part passed directly to carbonate, and in part to a whitish or yellowish, cloudy, nondescript material. Idiomorphic outlines of hornblende are occasionally preserved in this material. The carbonate is dolomitic or ankeritic in character, as dilute hydrochloric acid has very little action on the powdered rock in the cold. Chemical analyses of similar carbonates developed in the diorites near Wood's Point have shown them to be varying compounds of the carbonates of lime, magnesia, ferrous oxide, and manganous oxide. Chlorite still remains in considerable amount, but epidote has disappeared, having apparently succumbed to the action of the carbonate solutions. Local patches of carbonate in the chlorite are closely allied in shape to the epidote grains in the propylitic rock, and undoubtedly replace the latter mineral. Some of the chlorite is beginning to pass to colourless mica (muscovite), and carbonates have been intruded along the cleavage planes, and replace the chlorite in part. The felspars have been almost completely replaced by closely packed sericite flakes. Under high powers, these areas of sericite are resolved into a mixture of quartz and sericite. Carbonates are notably present in only very small amounts in the altered felspar.[1] The extent to which sericitisation has taken place in the wall rock, is shown by an analysis made for the alkalies. Thus :—Na_2O 0.21%.

K_2O 3.45%.

It will be remembered that in the original rock, soda was in marked excess of potash, and hence it must have been leached out during the alteration whilst the potash was fixed and probably more introduced. It is often assumed that the waters causing such sericitisation were relatively rich in salts of potassum and contained little sodium salts. I see no reason, however, for this assumption,[2] and since the vein solutions have passed through the diorite on their way to the surface they should presumably become richer in soda, and correspondingly weaker in potash, owing to sericitisation, as they approached the surface. Hence, even if the original uncontaminated waters were richer in potash salts than soda salts, the relative proportions of these constituents should soon become reversed. Probably the correct explanation is that under the conditions of temperature, pressure and concentration, existing at the time of the alteration, no stable sodium mineral could form. Paragonite and albite, for instance, are usually high temperature minerals, found in the crystalline schists and contact metamorphic deposits, and are very rarely formed under conditions of hydrothermal vein alteration. The potash mica corresponding to paragonite—namely, sericite, however, has a wide range of existence, occurring extensively in the crystalline schists, and almost invariably in rocks affected by vein solutions, and in the presence of the latter, it appears to be particularly stable. A very little pyrrhotite remains, but iron pyrites has increased considerably in amount. It is scattered through the rock, and shows no preference for regions where chlorite and ilmenite are most common. Quartz has suffered very little change as a result of these alterations. Its peculiar parallel cracks simulating a cleavage, still remain. On close examination under the high power, these cracks are seen to be not regular and straight, but to be occasionally curved and branching. Apatite, in general, is little changed. Occasionally it is fractured and replaced by carbonates. Ilmenite is almost entirely replaced by leucoxene.

1 Rosenbusch, "Elemente der Gesteinlehre," 1898, pp. 70-71, states that calcite, sericite, and quartz, are the products of the attack of carbonated waters on plagioclase felspars.

1 It might be suggested since sericitisation is accompanied by partial dehydration of the rock, that the vein solutions contained very little water ; yet presumably this is not so.

Specimen No. 138, illustrates the extremely altered wall rock near the veins. In hand-specimen, it is a greenish coloured fine-grained rock, greatly impregnated with pyrites, and veined by quartz carrying a little stibnite and carbonate. None of the original minerals of the diorite are recognisable. Microscopically chlorite has entirely disappeared, and is replaced by massive muscovite, giving a biaxial figure and having a fairly wide axial angle. Streaks of carbonate have formed along the cleavage planes. Iron pyrites, arsenical pyrites, and stibnite are all abundant in the altered wall rock. The iron pyrites is often present in irregular shaped grains, and when idiomorphic its form is usually the cube, or a combination of the cube and octahedron, and more rarely, the pyritohedron. Arsenical pyrites is more abundant than the iron pyrites close to the veins, and is readily distingushed from the latter mineral by its silvery lustre in reflected light, and by its idiomorphic outlines. Common forms are combinations of the unit prism and the brachydome, giving wedge-shaped and hexagonal sections. Cruciform twinning, which is so common in the arsenopyrite[1] from the Diamond Creek Dyke, is only rarely seen in the present case. Stibnite occurs singly in prismatic and acicular crystals and as a network of these fibres. When massive, it is silver-grey in reflected light. Some of this material, appearing metallic in reflected light, is deep red in transmitted light.[2] It is most common in the vein quartz, and in the quartz grains adjoining the vein wall. These three sulphides, although independently crystallised, are undoubtedly essentially contemporaneous in origin. Quartz still remains clear, but the grains are embayed, and partly replaced by carbonates. The ilmenite has entirely disappeared, and very little leucoxene remains anywhere in the section. Little pyrites, either the iron variety or the arsenical type, is present in the vein quartz, and the assumption is that the ilmenite and the chlorite have supplied the necessary iron to form the pyrites so abundant in the wall rock.

Summary of the effects of the vein solutions :—In the absence of a chemical analysis of the wall rock, no definite conclusions can be drawn with regard to chemical migrations of the original consti-

---

1 In the author's petrological description of the Diamond Creek dyke, arsenopyrite is mentioned as being possibly present. Further examination, however, shows it to be abundant near the vein fissures. Vide, N. R. Junner, Proc. Roy. Soc. Victoria, vol. xxv., p. 339, 1912.

2 Professor Migge was able to prove that stibnite showed straight extinction by examination of very thin flakes of the mineral between crossed nicols in direct sunlight. Vide Neues. Jahrb. Min., vol. i., p. 12, 1898.

tuents of the rock. The microscope, however, reveals the fact that sericite, carbonates, and pyrites are the ultimate products of the original minerals. It is evident that the solutions causing the alteration must have been rich in alkaline carbonates and sulphides. That they also contained arsenic and antimony, is apparent from the abundance of arsenopyrite and stibnite near the veins. The solutions undoubtedly were aqueous, yet the rock has probably suffered dehydration, which is explained by the disappearance of chlorite containing about 13% water, and its replacement by sericite containing only about 4%. A chemical analysis, of the wall rock adjoining a quartz vein in the Morning Star diorite, showed that the percentage of total water was 2.64 in the propylitised rock, and only 0.96 in the sericitised and carbonated facies. The efficacy of moderately strong alkaline carbonate solutions to dissolve rock-forming minerals is well known. Therefore, the extreme metasomatic alteration undergone by the original rock is easily explained as a result of the attack of such solutions. Gold is known to be soluble in alkaline sulphide solutions, and it was probably in such solutions that the gold in the veins at Yow Yow was introduced.

D.—Quartz Porphyry, One Tree Hill.

The eight inch to one mile geological map, published by the Victorian Mines Department, shows an outcrop of porphyrite at Smyth's Gully. The author is not aware of any such rock there, and apparently the rock intended to be shown is the One Tree Hill porphyry. This rock is seen on the surface, at the summit of One Tree Hill, adjoining the Buck line of reef, and is here decomposed to a mass of kaolin containing abundant quartz grains. It can also be seen on the track leading from the hill to the battery in Fern Tree Gully, and a tunnel driven from this gully into the hill to cut the Buck and Swedish reef intersected it. Where seen on the surface, the rock appears to be a dyke,[1] but the relations as revealed by the tunnel section, although not very clear, seem more suggestive of an intrusive pipe. The rock is greatly brecciated in places, and xenoliths of black slate, sandstone, and quartz porphyry are often included in it. Breccia and an agglomerate occur on the surface near the head of Fern Tree Gully, and also in the tunnel, but their relation to the normal igneous rock was not evident. The pebbles of the agglomerate are chiefly quartz porphyry, and are

1 The 1895 geologically coloured parish plan of Queenstown shows a diorite dyke at One Tree Hill.

usually sub-angular in shape, and rarely more than three inches in diameter. In the absence of field evidence to the contrary, it is possible, but not probable, that these supposed volcanic breccias and agglomerates have originated by faulting. The rock is intrusive, and the flow structure, which is characteristic of similar rocks from Lilydale, Steel's Creek, and north of the Black Spur, is absent in this case. Probably the rock fills what was once a volcanic conduit extruding rhyolitic lavas, which are now entirely denuded away. Hand-specimens of the rock are leucocratic and porphyritic, and show phenocrysts of quartz and altered felspar. A little pyrite is also present. Examined microscopically, the rock is seen to have been a quartz-felspar-porphyry, but its pristine characters are now greatly masked by extensive sericitisation, carbonation and occasional secondary silicification.

Section No. 132. The rock consisted originally of large clear panidiomorphic phenocrysts of quartz, fairly large euhedral crystals of felspar, and numerous crystals of a femic mineral, probably biotite, in a microcrystalline ground-mass of the same minerals. Apatite and zircon are accessories. As in the similar rocks described from Diamond Creek, quartz is the only mineral which has withstood the action of the hydrothermal solutions which have caused the alteration, to any marked extent. It is generally clear, and is often rounded and embayed by the ground mass. Such corrosion, however, is probably magmatic, and occurs in many volcanic and intrusive rocks not hydrothermally altered—e.g., Healesville dacites. Isolated inclusions of the ground mass, and numerous glass inclusions containing liquid bubbles, are present in the quartz phenocrysts. Cracks occur about some of these glass inclusions exactly as figured in Idding's "Rock Minerals," fig. 37b, p. 71. Pyramidally terminated crystals of zircon are also seen in the grains of quartz. The felspar phenocrysts have been extensively metasomatically replaced by dusty carbonates and microscopic flakes of sericite, with a little quartz. The alteration of the felspar has been so great in many sections that it can only be recognised by its well-preserved idiomorphic outline. Where the alteration has not been extreme, it can be generally proved without doubt that the felspar is predominantly orthoclase. Numerous included crystals of apatite, zircon, and muscovite occur in the felspar. The original femic mineral was probably biotite. It is now replaced by muscovite, and rutile has separated out,[1] however, not in the form of

[1] Biotite frequently contains a considerable percentage of TiO_2. A biotite from the Dandenong dacite, analysed by H. C. Richards, contained 7·95% TiO_2.

sagenitic webs as in the similar rock from Diamond Creek. Idiomorphic outlines of original felspar are abundant in the ground mass of the rock. They are now replaced by carbonates and sericite, and it is manifestly impossible to tell whether they are orthoclastic or plagioclastic. Abundant granular impellucid carbonate occurs throughout the section replacing both phenocrysts and minerals of the ground mass. The powdered rock effervesces readily when dilute hydrochloric acid is added in the cold, proving that the carbonate is chiefly calcite. Iron pyrites is present in nearly all sections. It is often idiomorphic, consisting of the following forms: —110, 100, and combnations of 100 and 111. The crystals are often surrounded by a rim of secondary quartz arranged radially with respect to the crystal edges. Such quartz may possibly represent recrystallised silica, formed by the attack of sulphuretted hyrogen or alkaline sulphide solutions on the original iron magnesium silicates.

Section No. 135. Brecciated porphyry, One Tree Hill. The felspars in this section are not so greatly altered. Phenocrysts of both orthoclase and plagioclase are present, but the former mineral predominates. It is frequently very greatly sericitised and carbonated, and appears to contain microperthitic intergrowths of albite. One plagioclase phenocryst gave symmetrical extinctions of 20° from the albite twin lamellae, and had a refractive index greater than quartz, indicating felspar near andesine.

Section No. 125. Xenolithic fragments of sandstone are present in places in this section. They show no resorption, and are composed of angular and sub-angular quartz grains, flakes of muscovite, and a little zircon, and brown tourmaline.

Related rocks from the country east of Melbourne.—Acidic dyke rocks (quartz porphyry, felsite, and diorite dykes, of various writers) are fairly common in Victoria, associated with intrusions of granite and granodiorite. East of Melbourne they are fairly numerous, and are known from Diamond Creek, Warrandyte, Templestowe, Frankston, Kinglake, Ringwood, and several other places. Similar rocks near Steel's Creek, Lilydale and Mount Graham are probably the extrusive facies of the same magma. These dykes are usually altered metasomatically, in much the same manner as in the rock described above, from One Tree Hill, and are often traversed by, or associated with, auriferous quartz veins which almost invariably contain stibnite. Auriferous dykes are known at Diamond Creek, Warrandyte, Templestowe, Kinglake, Scotchman's Creek, near Warburton, and elsewhere. About three miles north of Steel's Creek, an apparently extrusive mass of rhyolite is traversed by quartz veins carrying abundant stibnite, which is auriferous in places.

3.—The Caledonia Gold Field.

A.—History and Production.

Although now abandoned and unknown to most people, the reefs and alluvial of this field have yielded more gold than the better-known Warrandyte reefs. The gold obtained from the Caledonia field has come almost exclusively from the reefs at One Tree Hill, Panton Hills, and Yow Yow, and from the alluvia of the creeks draining these areas. The field was being worked at least as early as 1855, although no official records prior to 1859 are extant. The report of the Mining Surveyor for September, 1859, states that there were 420 miners on this field. In the late fifties and early sixties the One Tree Hill reefs, particularly the Swedish, yielded exceptional returns, but they soon gave place as producers to more consistent reefs like Oram's reef, Panton Hills, and except for occasional very rich yields, later outputs have been unimportant. Oram's reef was a very consistent producer from the time of the discovery in 1859 until about 1885. During this period it averaged three ounces to the ton (a record equalled on very few mining fields), and at the greatest depth reached, the yields were even richer than those from the upper workings. By far the greater part of the gold won from Panton Hills came from this line of reef. Such others as the Napoleon reef, Boomer's reef and Doctor's reef, have yielded only a small quota. The reefs at One Tree Hill and Panton Hills, and also those near Queenstown, are all in close proximity to anticlinal fractures, but those at Yow Yow are of a different type. These reefs occur in the intrusive diorite and in the fractured country rock adjoining the intrusion, and although they have not been so rich as Oram's reef or the Swedish reef, they have nevertheless at various times contributed largely towards the district total. Another important asset to this field was the discovery of coarse gold in the alluvium of certain creeks, particularly in those at Happy Valley, Fern Tree Gully, and Whisky Gully, which have their source in One Tree Hill. These creeks afforded remunerative employment to numerous miners for many years, and some fairly large nuggets (one of them weighing over 100 ozs.) were unearthed.

The alluvial diggings, however, were soon exhausted, and after about the year 1880, this source of gold became unimportant.

Production :—In compiling statistics of gold production, the author has made considerable use of the Quarterly Reports of the Mining Surveyors and Registrars from 1859 to 1891, and of the Annual Reports of the Mines Department from 1891 to 1911. As the latter publication gives only isolated rich yields, and not the complete returns, for the greater part of the above period, any statistics so obtained are necessarily incomplete. The records show that up to 1890, nearly 25,000 ozs. of gold were won from the quartz reefs, distributed thus in round figures :—

Panton Hills	9000 ozs.
One Tree Hill	7500 ozs.
Yow Yow	7500 ozs.

Valued at £4 an ounce; this is equivalent to nearly £100,000 worth of gold. Two thousand ounces is a very conservative estimate for the production between 1890 and 1912, so that the total yield from the field, exclusive of the yield from the alluvial, is well above £100,000. No complete returns of the gold obtained from alluvial sources are possible, as the records are far from being complete.

B.—One Tree Hill.

The productive reefs at One Tree Hill run parallel, and at short distances apart, all outcropping at the top of the hill, within a width of 200 yards. The strike of these reefs varies from N. 15° E. to N. 20° E., corresponding closely to the strike of the contiguous sediments which are here chiefly brown and white sandstones, in places indurated and changed to quartzite. At the south end of the hill one or two small quartz reefs strike across the country rock, but as far as the author is aware very little gold has been obtained from them. The most important reefs worked at One Tree Hill are from east to west, the Buck, Moonlight, Swedish, and the Homeward Bound. Further east than the Buck line are one or two other reefs, the most important of which is the Victoria reef. It was prospected in the late fifties and early sixties, but, according to the records, little gold was obtained. All these reefs dip at fairly steep angles, frequently approaching the vertical, and cut across the strata in depth. In this respect they resemble the reefs at Warrandyte. The Buck line of reef has been extensively developed by means of a tunnel driven from Fern Tree Gully. This tunnel intersects the porphyry above described, and the Buck reef occurs at the contact of this rock with the Silurian sandstones, and dips very steeply to the west. The reef is here composed of compact milky quartz, slightly mineralised. Pyrites is the dominant sulphide, and stibnite is relatively rare, as compared with its abundance in the reefs at Yow Yow. Native lead has been recorded from the Homeward Bound reef,[1] pointing to the presence of a fairly easily reduced lead mineral. It is interesting to note that native lead has also been recorded from the quartz reefs at Warrandyte,[2] and from the Ringwood antimony mine.[3] According to the Mining Surveyor for the division, the Buck reef was the widest and poorest reef at One Tree Hill. Its average width was about three feet although it was as much as six feet wide in places. The Reports of the Mining Surveyors show that from this reef 2126 ozs. of gold were obtained from 3313 tons of quartz crushed, between the years 1866 and 1873. This practically represents the total yield recorded from the Buck reef, although not the total gold won, as the records are undoubtedly incomplete, and the Reports mention it as being reworked in 1866, after having been abandoned.

The Swedish reef was one of the earliest developed in this field. It is well defined on the surface, and strikes N. 25° E. to N. 30° E., and dips to the south-west, at about 60°. Numerous shafts have been sunk on its outcrop, but practically none of them descend to greater depths than 200 ft., and the majority are less than 100 ft. deep. The Swedish reef gained notoriety in 1859 and 1860, owing to the discovery of some very rich patches of gold near the surface. A few of the earliest recorded yields, undoubtedly from picked specimens, may be quoted to illustrate the extraordinary richness of the quartz, and the nuggety character of the gold.

The early records are far from complete, and, according to the Mining Surveyor, many of the miners were unwilling to divulge the returns. The discrepancy between recorded and actual yields is well illustrated by the Mining Surveyor's Report for January, 1861. He says, speaking of the Swedish reef: "The former owners were about to abandon No. 2 South, on the eve of their finding quartz, yielding, from a few patches, about £8000 worth of gold." At £4 an ounce this gives 2000 ozs. of gold, yet the recorded yield amounted to only 620 ozs. Apart from these very rich patches,

1 Annual Report, Sec. Mines, Victoria, 1911.

2 Vide, J. Atkinson: A locality list of all the minerals hitherto recorded from Victoria, Proc. Roy. Soc. Victoria, vol. ix. (n.s.), p. 96, 1896.

3 Vide, Mineral Statistics of Victoria, 1877.

Date.		Depth ft.	Quartz. crushed.	Total yield of gold.	Average ozs. per ton.
June,	1859	21	90 lbs.	144 ozs.	3584
August,	1659	21	60 lbs.	240 ozs.*	8960
January,	1860	64	1 bucket of ore	80 ozs.*	—
March,	1860	—	57 lbs.	272 ozs.*	10680
March,	1860	—	specimen	48 ozs.*	—
	1864	—	65 tons	780 ozs.	12
	1865	50	16½ tons	349 ozs.	21.2
	1865	50	13 tons	134 ozs. 7 dwts.	10.3
	1865	—	2 tons	86 ozs.	43
	1865	—	8 tons	138 ozs.	22.9
	1865	—	10 tons	125 ozs.	12.5

* Recorded in pounds weight, probably pounds avoirdupois, as it was usual in the early mining days to weigh the gold in pounds avoirdupois.

much gold was obtained from the inferior grade quartz, which averaged 4 ozs. to the ton, at 65 ft. The brilliance of the Swedish reef was short-lived, and, after 1870, little more was heard of it.

C.—Panton Hills (Oram's Reef).

As previously mentioned, productive quartz mining at Panton Hills has been almost entirely confined to one line of reef—namely, Oram's. This reef was first opened up during 1859, and it yielded fairly consistently until 1885. After this isolated rich yields were obtained, mostly from the ground previously worked over. The reef outcrops on the east side of the main road from Kangaroo Grounds to Queenstown and Kinglake. It strikes approximately N 25° E., and dips to west. Its width varies from two inches to three feet, and it consists of laminated white quartz, rarely crystalline. Oram's reef has been developed to a depth of nearly 400 ft., and longitudinally for a distance of about half a mile, and has yielded approximately 9000 ozs. of gold; more than 8000 ozs. of which were obtained between the years 1865 and 1885. No gradual change, and certainly no decrease in values, occur in depth, as is evident from the following table compiled from returns recorded in the Mining Surveyor's Reports between 1866 and 1885. Only those returns were used which gave the depth from which the ore was obtained.

Depth from Surface.	Tonnage Crushed.	Total Yield.	Av. per ton.
0– 59 ft.	120½	249 ozs. 4 dwts.	2 ozs. 1 dwt.
50–100 ,,	231½	564 ,, 4 ,,	2 ,, 9 dwts.
100–150 ,,	197½	901 ,, 5 ,,	4 ,, 11 dwt.
150–200 ,,	278	1207 ,, 4 ,,	4 ,, 7 ,,
200–250 ,,	358½	864 ,, 12 ,,	2 ,, 8 ,,
250–300 ,,	674½	2369 ,, 17 ,,	3 ,, 10 ,,
300–370 ,,	—	—	5 ozs.

These returns show that the richest ore was obtained from between 100 and 200 ft., and that the ore from shallow depths was poorer in value than that from the deeper workings. No inferences can be drawn with safety from these yields, respecting the effect of secondary enrichment on the auriferous quartz. The ground water level occurs at a depth of about 200 ft., and the richest quartz came, therefore, from above this level; although the 300 ft. level alone yielded 2000 ozs. of gold, equivalent to nearly one-fourth of the total gold won from this reef.

D.—Yow Yow.

Several quartz veins have been prospected, with varying success, near the Yow Yow diorite intrusion. The best known of these reefs are Allen's, Eureka, Comet, Murray's, No. 5, and Hirt's reefs. The records show that Allen's reef was the largest producer of these, but, owing to the multipilicity of names of claims and reefs, it is manifestly impossible to calculate the yields from individual reefs with any degree of exactness. Allen's reef varied in width from two to three inches, up to the corresponding number of feet, and was not worked at greater depths than 200 ft. The reef occurs within the diorite, and according to the Mining Surveyor, the yields from the hard, undecomposed rock were just as rich, or even richer, than those from near the surface. With the exception of the Caledonia, none of these reefs have been worked below 200 ft. At this mine a shaft has been sunk between 200 and 300 ft. in depth, and several very thin, nearly vertical dipping, veins, have been worked. These, however, were unprofitable in depth, not because of any decrease in values, but owing to the great amount of very resistant diorite which had to be extracted with the quartz. Stibnite is the predominant vein sulphide, and pyrites and misnickel are sometimes present. Massive stibnite occurs in several of these reefs, especially those situated on the west and north-west sides of the diorite. Calcite is a fairly common gangue mineral. The gold is of a high degree of fineness, as is usual elsewhere in Victoria, where stibnite is the predominate vein sulphide, and is generally valued at more than £4 an ounce. Nearly all these reefs strike between north and north-east, and dip at steep angles. An approximate estimate of the gold recorded from Yow Yow may be stated as 8000 ozs., of which total, more than one-third (about 2700 ozs.) has been recorded from Allen's reef. The Eureka was also an important contributor, and over 1500 ozs. were won from this line of reef. Certain of these auriferous veins, worked within the diorite, pass out into the sediments, and have been found to be payably auriferous for some distance from the intrusion.

E.—Alluvial.

The bulk of the alluvial gold from this field came from the creeks draining One Tree Hill; and, compared with the gold obtained from them, other returns are unimportant. The gold was almost invariably of the nuggety type, and one nugget of 103½ ozs. was unearthed in Cobbler's Gully. The occurrence is of interest, since elsewhere in Victoria large nuggets are generally associated with Ordovician strata, and nuggets of over 100 ozs. have been recorded in only two other areas—namely, Alexandra, and Wood's Point,[1] where undoubted silurian sediments are the country rock. The following is a list, probably not complete, of nuggets recorded from the alluvial near One Tree Hill :—

A.—Cobbler's Gully, or Happy Valley.

Weight.	Depth from surface.	Reference.	Remarks.
103½ ozs.	6 feet	Q.R.M.S. Dec. 1874[2]	100 ozs. 12 dwts. fine
88 ,,	—	,, Sept. 1860	
84 ,,	Shallow	,, Oct. 1860	78 ozs. fine.
83 ,, 6 dwts.	6 inches	,, Mar. 1870[3]	
72 ,,	—	,, Oct. 1860	Several small nuggets
42 ,,	—	,, Nov. 1860	

1 Vide list of nuggets found in Victoria. Mem. Geo. Surv., Victoria, No. 12, 1912.
2 Quarterly Reports of the Mining Surveyors and Registrars of Victoria.
3 Mixed with quartz. Found in the alluvial of the Swedish reef, 50ozs. fine.

Weight.	Depth from surface.	Reference.	Remarks.
40 ,,	—	,, Sept. 1860	
32 ,, 12 grs.[1]	—	,, Aug. 1860	
28 ,, 11 dwts.	6 feet	Prog. Rep. No. 3, 1875	Estimated 17 ozs. 12 dwts.
17 ,, 12 ,,[2]	12 ,,	Q.R.M.S. Dec. 1874	
11 ,,	15 ,, 6 in.	,, May 1860	
5 ,, 17 ,,	12 ,,	,, Dec. 1874	

B.—Fern Tree Gully.

Weight.	Depth.	Reference.	Remarks.
56 ozs.		Q.R.M.S. Dec. 1880	In two nuggets.
32 ,, ?		,, Mar. 1862	
24 ,,		,, Jan. 1862	
20 ,,		R. B. Smyth, Gold Fields of Victoria, 1868	
10 ,,		M.S.R.[4] Feb. 1861	
10 ,,		,, Jan. 1861	
8 ,,		,, Jan. 1861	
8 ,,		,, Jan. 1861	

C.—Whiskey Gully.

Weight.	Depth.	Reference.	Remarks.
34 ozs. 13 dwts.	11 feet	Q.R.M.S. June 1869	
9 ,,		,, Sept. 1861	
3 ,, 5 dwts.[3]	,,	,, June 1869	

According to the district Mining Surveyor, other large nuggets were found and not reported by the finders. The evidence is absolutely convincing that these nuggets have been shed from the reefs, and that they have not grown in situ. Firstly, it is a well-known fact on this field that the richest alluvial has always been found in close proximity to fairly rich reefs—e.g., One Tree Hill. Further in Cobbler's Gully, nuggets have been found in all posi-

1 Recorded from Fern Tree Gully or Happy Valley.

2 Possibly identical with the preceding nugget.

3 Probably Fern Tree Gully, as all nuggets from Cobbler's Gully were obtained at shallow depths.

4 Mining Surveyor's Reports.

tions, from well down the gully right up to the outcrop of the reefs on One Tree Hill. The district Mining Surveyor in 1870 reports the finding of a rich specimen of quartz (83 ozs. 6 dwts. gross weight, 50 ozs. fine) six inches below the surface reef, and undoutedly derived from this reef. The nuggets found nearest the reefs are generally mixtures of quartz, limonite and gold, and show little signs of rounding. Cobbler's gully has yielded the largest nuggets, and there is every reason to believe that they have been derived from the Swedish reef, which has been shown to be a nuggety reef, and much of the gold obtained from it would be best described as nuggets. For instance, a specimen of quartz from this reef, having a maximum dimension of 3 inches, was found to yield 48 ounces of gold.[1] Mr. Hirt, who has had a very intimate acquaintance with this field, told the writer in private conversation that a nugget 40 ozs. in weight, and associated with quartz and limonite, was got from a depth of nearly 100 feet in a claim on the Homeward Bound line of reef. It will be agreed, I think, that the evidence allows of no other conclusion than that the nuggets have been derived by the breaking down by denudation of the former upward extension of such reefs, as the Swedish at One Tree Hill.

F.—Future possibilities, Secondary enrichment, etc.

Oram's is the only reef on this field developed at greater depths than 300 feet, and the majority of the workings have not penetrated below the ground water level. Notwithstanding the shallowness of the workings, there is apparently nothing to show that the values have not been maintained in depth, as is seen from the figures given above for Oram's reef. Of the geological factors that may have influenced the values near the surface, secondary enrichment is the most important. The recognition of its effect on auriferous quartz veins, is frequently difficult, and this is especially so in Victoria. Victorian gold is generally of a high degree of fineness, and usually free from sulphides of the base metals which are easily leached, and either oxidised or redeposited at lower levels as secondary sulphides. Further, most of these mines were developed before secondary enrichment was studied, and practically no facts relevant to the question are now obtainable from the records. The yields from various depths aid us little, as is seen from the tabulated

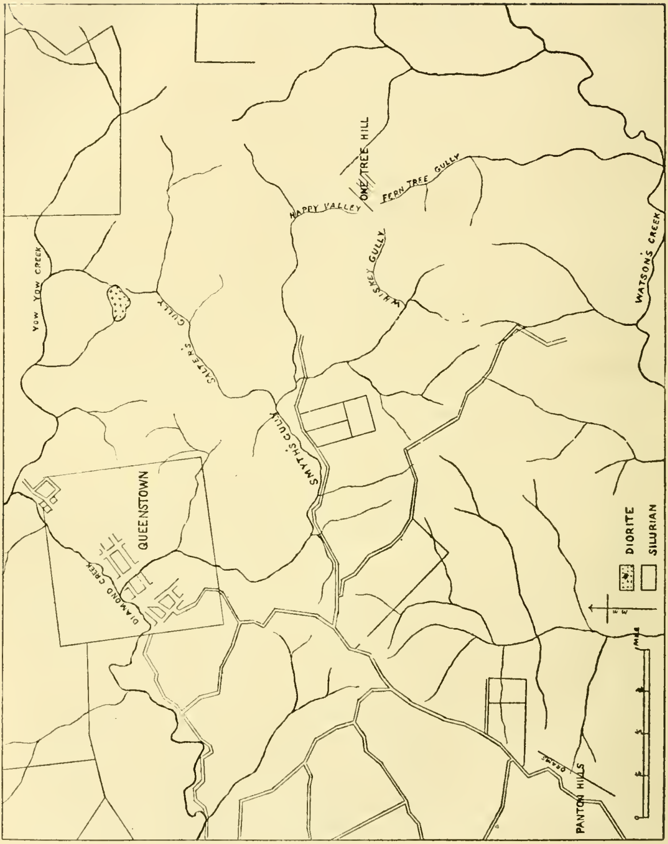
1 Vide, supra, p. 36.

yield of Oram's reef. Hence, no conclusions can be drawn with certainty regarding the effects of secondary enrichment on these reefs, but the evidence, such as it is, supports the conclusion that the values have not been greatly affected. The thin character of the reefs, combined wtih their comparative density, tends to inhibit extensive circulation of surface solutions, and hence to prevent solution of the gold. The rich patches found near the surface at One Tree Hill might be considered as suggestive of secondary enrichment, but the evidence, although not conclusive, does not support such a view. It appears fairly evident from the nuggets found in the alluvial at Cobbler's Gully, that the former upward extension of the Swedish reef was as rich, or even richer, than the portion now exposed to denudation and vadose solutions. It seems very likely, therefore, that the distribution of the gold in the Swedish reef near the surface, is not due to the present-day vadose circulation, but is due to conditions determining the primary deposition of the gold. Of such factors influencing the primary deposition, decrease of temperature and pressure, admixture with surface solutions, and indicator effects are the most important. There is fairly good reason to believe that the formation of these reefs took place soon after the folding of the sediments, and it is certain that several thousands of feet of these have been denuded away. Hence the assumption does not seem to be unwarranted that the primary deposition of the gold, in the portion of the reef now exposed, was not affected by admixture with surface solutions, and presumably not to any marked degree by reduction of temperature and pressure. We are left to deal with the effects of indicators. At Ballarat East, where nuggety gold occurs in the reefs, often at considerable depths, the nuggets are localised to near the intersection of the vein quartz with their seams termed "indicators." Unfortunately, the Swedish reef at One Tree Hill was not being worked at the time of my visit, and the records do not mention the mode of the occurrence of the gold, so that positive evidence, bearing on this question, is not forthcoming. However, Mr. Hirt, who, as previously mentioned, has been on this field most of his life, and whose word I have no reason to doubt, has informed me that the rich patches of gold, from the Swedish reef, were generally localised to near the intersection of the main reef with rather flat leaders of pinkish coloured quartz, two inches or so in width. If this is so, there appears to me to be no valid reason why other "indicator" veins and rich patches of gold should not be found in depth. As far as I am aware, the Swedish reef has not been prospected below 200 feet, although the records mention the driving of a tunnel from Fern Tree Gully to prospect the Swedish reef in depth, but it is doubtful whether they ever worked this reef. Messrs. Hirt and Gerlach have recently driven a tunnel from the head of Cobbler's Gully to cut the Swedish reef, but at the time of my visit, they appeared to have not been successful in locating it. It is at least certain that there is no geological evidence in support of the view that the gold does not go down, and in the case of the Swedish reef the possible occurrence of other rich patches of gold in depth, has not been disproved. From the birth of this field the reefs have been worked almost entirely by individual miners or small parties, and companies were practically unknown. This is probably one important reason why the mines were abandoned at such shallow depths. The presence of water and the need of pumping machinery, harder ground, increased haulage, and the difficulty of following such narrow reefs, all contended against the enterprising individual, but such mines could, in many cases, be worked at a profit by small companies, with judicious expenditure and economical methods of working.

4.—Summary and Conclusions.

Until further palaeontological work has been attempted in this area, no definite opinion can be expressed relative to the age of these beds, near Queenstown. A stratigraphical comparison with the strata at Diamond Creek and Yarra Glen, suggests that they are intermediate in age between those at the above places, and are, therefore, either Melbournian or Yeringian. It is, however, possible that both series are represented in the area dealt with in this paper.

Although diorite is a popular field name for many rocks in Victoria, chemical and petrological examination show that true diorites are exceptional. The association of hornblende diorites, with gold-bearing quartz in Eastern Australia, is not uncommon. The extensive metasomatic changes undergone by these rocks frequently accompanies the introduction of the auriferous quartz. The Queenstown diorite has been shown to be closely allied to the Morning Star diorite, Wood's Point, and has suffered similar alteration. Two independent types of metasomatic alteration can be recognised in the Queenstown diorite—(1) A propylitic alteration at relatively high temperature and pressure, resulting in the formation of chlorite and epidote after hornblende; the development of pyrrhotite



Geological Sketch Map of portion of the Parishes of Queenstown and Greensborough. Reproduced from Mr. O. A. L. Whitelaw's maps of these Parishes.

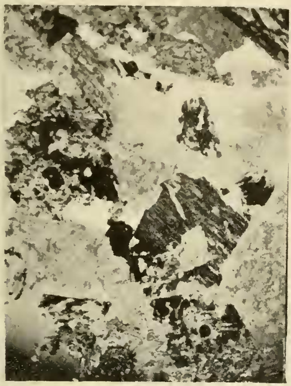


Fig. I.

Fig. II.

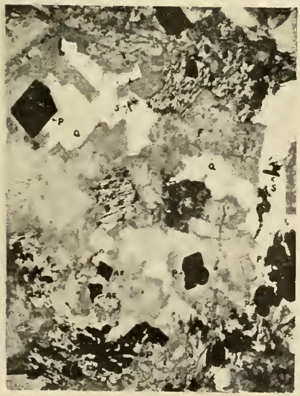


Fig. III.

Fig. IV.